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Measured Performance of Low-Sidelobe Narrow-Wall Slotted Waveguide Planar Antenna in Millimeter-Wave Band

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1. Introduction

Low sidelobe slotted waveguide antenna is developed in the millimeter-wave band. Millimeter-wave technologies are expected to apply to automotive radars and high-bit-rate mobile communication systems because high gain and narrow beam-width is possible even though the physical size of the antenna aperture is small. Waveguide antenna is advantageous for high gain applications since the feeding loss is small in the waveguide. Sidelobe level should be low because sidelobe causes miss-detection in radar applications and interference in communication systems. In the design of low-sidelobe slotted waveguide array antenna with traveling-wave excitation, wide range of slot radiation control is required since difference is large between assigned slot-couplings around the input port and around the termination. We have already developed a slotted waveguide planar array antenna composed of post-loaded slots [1] and feeding circuit of post-loaded T-junctions [2]. In order to confirm the potential range of radiation control for these components, we design the antenna with sidelobe lower than −30 dB for target in this paper. Design and measured performance of the developed antenna are presented in this paper.

2. Configuration and Design of Planar Antenna

We designed the planar antenna with gain higher than 30 dBi. Antenna configuration is shown in Fig. 1. The antenna is with 45-degrees diagonal polarization to apply to automotive radar systems and is composed of one feeding waveguide and 24 radiating waveguides slotted on the narrow walls. The input port of the feeding waveguide is at its center and all the radiating waveguides are fed from the feeding waveguide in the cascade connection. The radiating waveguides are connected on the broad wall of the feeding waveguide. Since adjacent waveguides are spaced in a half guided-wavelength of the feeding waveguide, they are fed in an alternating 180-degree out of phase.

2.1 Configuration and Design of Slotted Radiating Waveguide

We designed a linear slot array on a radiating waveguide. A configuration of a post-loaded waveguide slot with open-ended cavity is shown in Fig. 2(a). The slot element is designed at 76.5 GHz. The slot is cut on the waveguide narrow wall and is inclined by 45 degrees from the guide axis. The slot spacing becomes one guided wavelength which is longer than a wavelength in free space. In order to reduce the guided-wavelength, the broad-wall width *a* is determined to be large within the limit that only TE_{10} mode propagates. Radiation from the slot is enhanced by using the post in the waveguide.

Thirteen slot-elements on the linear array are numbered from the feed point to the termination. Required coupling power from slots are assigned for Taylor distribution on the aperture to be a sidelobe level lower than −30 dB as shown in Fig. 2(b). A required variety of coupling is 1.0 % ∼ 66.6 %. It is 14.2 % wider than −20 dB design. In order to design the antenna with low sidelobe, wide range of radiation control from slot is required since difference is large between assigned slot-couplings around the input port and around the termination.

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2. 2 Configuration and Design of Feeding Circuit

The planar antenna is composed of one feeding waveguide and 24 radiating waveguides slotted on the narrow walls. The antenna input port is located at the center of the feeding waveguide. All the radiating waveguides are fed from the feeding waveguide in the cascade connection. The radiating waveguides are connected on the broad wall of the feeding waveguide, which forms a series of E-plane T-junctions shown in Fig. 3(a). Since adjacent waveguides are spaced in a half guided-wavelength of the feeding waveguide, the radiating waveguides are fed in an alternating 180-degree out of phase.

Required coupling power in each radiating waveguide is assigned to realize Taylor distribution on the aperture as is shown in Fig. 3(b) to be a sidelobe level lower than −30 dB as well as the design of slotted linear array mentioned in the previous section. Since the feeding waveguide is fed at the center and the feeding circuit is symmetrical configuration, required coupling power for the radiating waveguides is large around the feeding point. E-plane T-junction of extremely small coupling is not needed as required for radiating slot. A required variety of coupling is 17.1 % ∼ 56.4 %. It is only 0.5 % larger than the conventional design. Required range of coupling power for the radiating waveguide is not very large because input port is at the center of the feeding waveguide.

3. Measured Performance

We measured two-dimensional near-field aperture distribution of the antenna at 76.5GHz and computed the radiation patterns by fourier transformation of the measured near field data. Figure 4 shows the measured and designed radiation patterns in the plane parallel to the radiating waveguide. The main beam directs to the broadside as the same with the design. The sidelobe level is −22.0 dB which is 8.0 dB higher than the design. However, it is 5.2 dB lower than the antenna of conventional design [3]. Figure 5 shows the measured and designed radiation patterns in the plane parallel to the feeding waveguide. The measured main beam direction results in −1 degrees from design. The sidelobe level is −20.2 dB which is 9.8 dB higher than design. It is almost the same level with the antenna of conventional design.

The measured gain and antenna efficiency at the frequency from 75.5 GHz to 78 GHz are shown Fig. 6(a). The center frequency shifts in 500 MHz from the design frequency 76.5 GHz to 76.0 GHz. The gain is 32.0 dBi and the antenna efficiency is 48.1 % at 76.0 GHz. The measured reflection characteristics are indicated in Fig. 6(b). The measured reflection level is −10.2 dB at 76.5 GHz. This return loss causes 9.5 % degradation of antenna efficiency.

4. Conclusion

We designed a low-sidelobe slotted waveguide planar antenna in the millimeter-wave band. The measured performance is evaluted by comparison with the electromagnetic simulation in this paper. Effect of post-loaded slots and feeding circuit of post-loaded T-junctions are confirmed as sidelobe levels were -22.0 dB in the plane parallel to the radiating waveguide and -20.2 dB in the plane parallel to the feeding waveguide. These levels are lower than the comventional ones.

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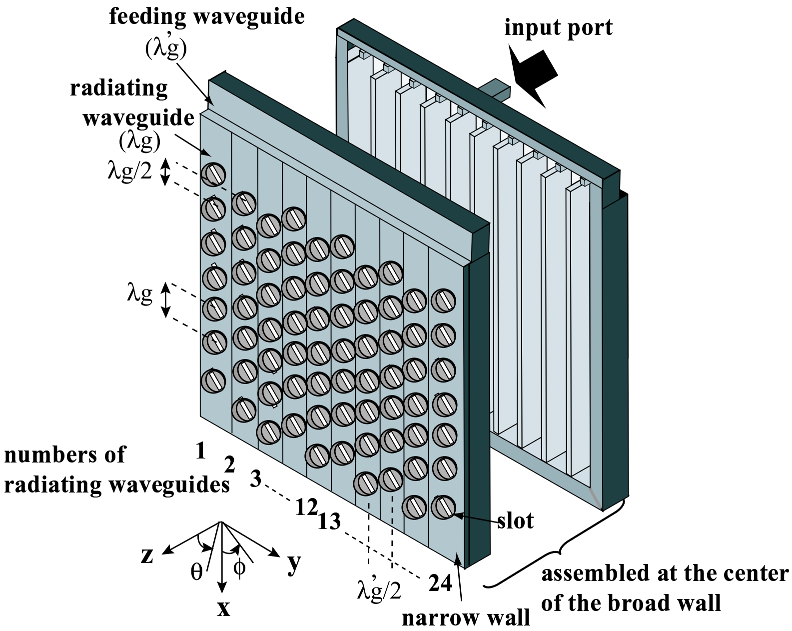
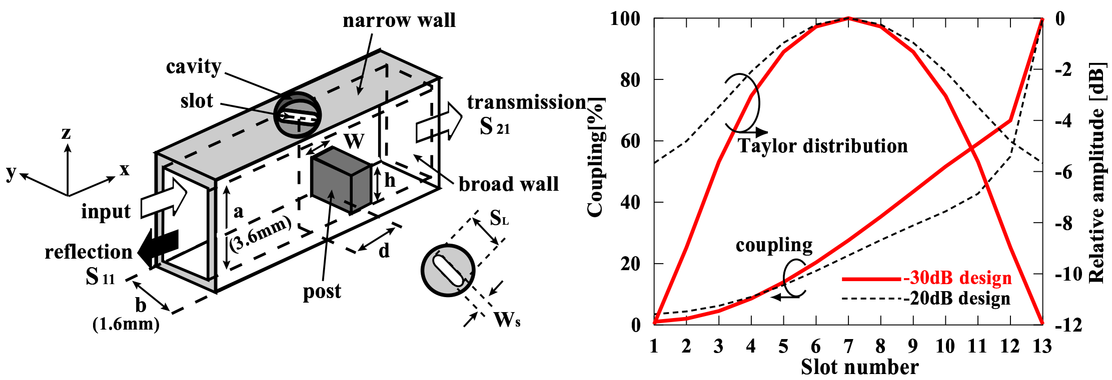
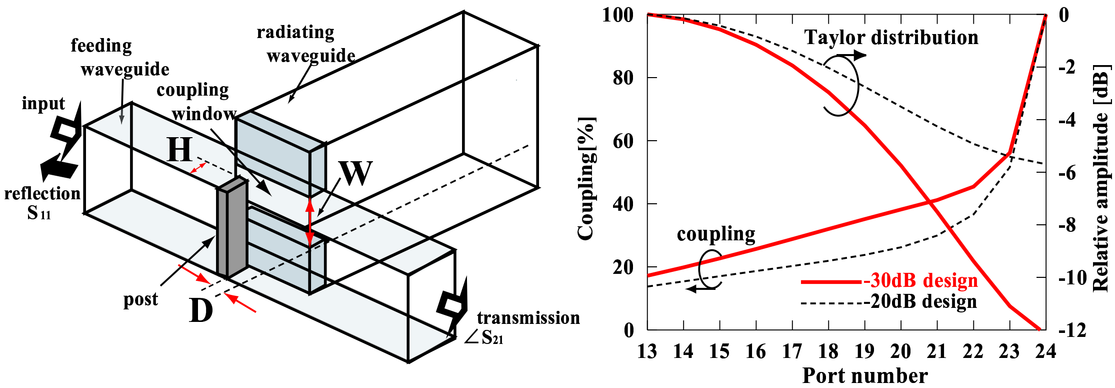


Figure 1: Configuration of designed planar array antenna



(a) Configuration of a post-loaded waveguide slot **(b) Coupling and Taylor distributions**

Figure 2: Configuration of a post-loaded slot and comparison of designs with sidelobe −30 dB and −20 dB



(a) Configuration of T-junction **(b) Coupling and Taylor distributions**

Figure 3: Configuration of a post-loaded T-junction and comparison of designs with sidelobe −30 dB and −20 dB

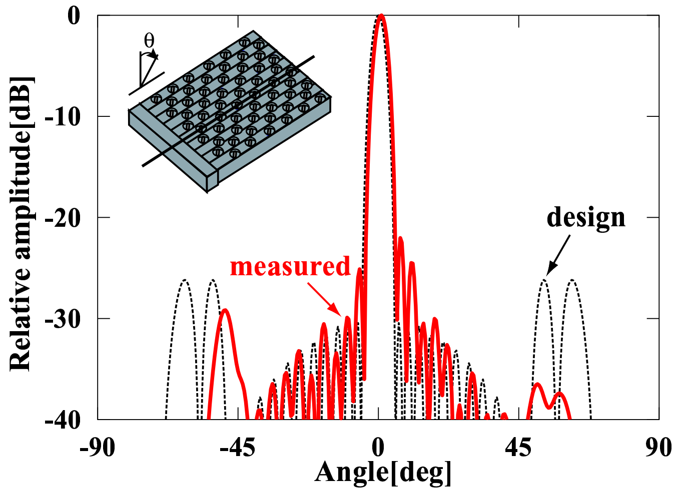


Figure 4: Measured radiation patterns in the plane parallel to the radiating waveguide

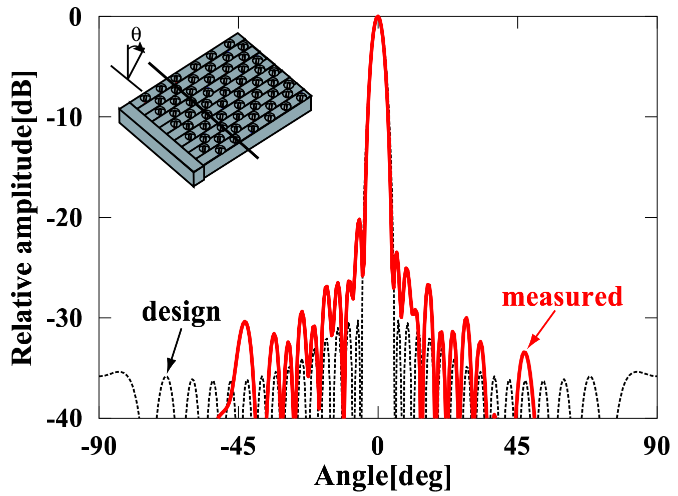


Figure 5: Measured radiation patterns in the plane parallel to the feeding waveguide

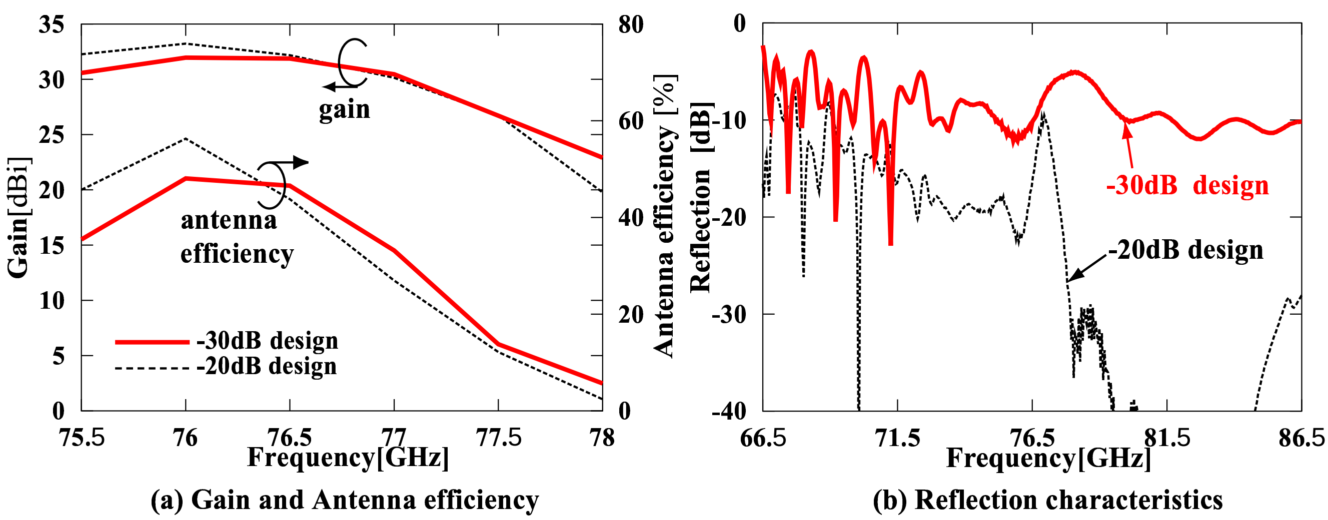


Figure 6: Measured frequency dependency of gain , efficiency and reflection at the input port